

Appl. No.: 10/531,132
Applicant(s): Normark & Ståhlberg
International Appl. No.: PCT/SE03/001544
International Filing Date: October 3, 2003

Amendments to the Claims:

Please amend Claims 22 and 28 and add new Claims 29-35 as follows:

1. (previously presented) A method of processing spread spectrum signals comprising:
 - receiving a continuous signal (S_{IF}) of a comparatively high frequency;
 - sampling the continuous signal (S_{IF}) at a basic sampling rate (r_s), whereby a resulting sequence of time discrete signal samples ($S[s_i]$) is produced;
 - quantizing each signal sample into a corresponding level-discrete sample value;
 - forming of a plurality of data words ($d(1), \dots, d(N)$) which each includes one or more consecutive sample values (s_1, \dots, s_n); and
 - correlating between information in the data words ($d(k)$) and at least one representation ($CS(i)$) of a signal source specific code sequence (CS), the method comprising preparing for the correlation step, wherein, before receiving the continuous signal (S_{IF}), a multitude of code vectors ($CV; CV_m$) are pre-generated, each code vector representing a particular code sequence ($CS(i)$) of the at least one signal source specific code sequence (CS), and
 - the correlating step involving multiplying at least each vector in a sub-group ($CV_{m-E}, CV_{m-P}; CV_{m-L}$) of the code vectors ($CV; CV_m$) with at least one vector ($S_{IF-I}(k); S_{IF-Q}(k)$) derived from the data word ($d(k)$).
2. (previously presented) A method according to claim 1, wherein each code vector ($CV; CV_m$) represents a particular signal source specific code sequence ($CS(i)$) being sampled at the basic sampling rate (r_s) and quantized with the quantizing process being used to produce the level-discrete sample values (s_1, \dots, s_n).
3. (previously presented) A method according to claim 1, wherein the at least one signal source specific code sequence (CS) is pseudo random noise.

4. (previously presented) A method according to claim 1, wherein the receiving step involving down conversion of an incoming high-frequency signal (S_{HF}) to an intermediate frequency signal (S_{IF}), the high-frequency signal (S_{HF}) having a spectrum which is symmetric around a first frequency (f_{HF}) and the intermediate frequency signal (S_{IF}) having a spectrum which is symmetric around a second frequency (f_{IF}) being considerably lower than the first frequency (f_{HF}).

5. (previously presented) A method according to claim 4, further comprising the steps of:

determining a maximum frequency variation (f_D) of the second frequency (f_{IF}) due to Doppler-effects;

defining a Doppler frequency interval ($f_{IF-min} - f_{IF-max}$) around the second frequency (f_{IF}), the Doppler frequency interval (f_{IF-min}, f_{IF-max}) having a lowest frequency limit (f_{IF-min}) equal to the difference between the second frequency (f_{IF}) and the maximum frequency variation (f_D), and a highest frequency limit (f_{IF-max}) equal to the sum of the second frequency (f_{IF}) and the maximum frequency variation (f_D);

dividing the Doppler frequency interval ($f_{IF-min} - f_{IF-max}$) into an integer number of equidistant (Δf) frequency steps ($f_{IF-min}, f_{IF-min}+\Delta f, \dots, f_{IF-max}$); and

defining a frequency candidate vector (f_{IF-C}) for each frequency step ($f_{IF-min}, f_{IF-min}+\Delta f, \dots, f_{IF-max}$).

6. (previously presented) A method according to claim 5 further comprising the steps of:

determining an integer number of initial phase positions (ϕ_0, \dots, ϕ_7) for the frequency candidate vector (f_{IF-C}), and

defining a carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) for each combination of carrier frequency candidate vector (f_{IF-C}) and initial phase position (ϕ_0, \dots, ϕ_7).

7. (previously presented) A method according to claim 6 further comprising the steps of:

determining the number of elements (s_n) in each carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$); and

storing the carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) according to a data format being adapted to performing multiplication operations between the data word ($d(k)$) and a segment of a carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$).

8. (previously presented) A method according to claim 7, wherein adapting of the data format involves adding at least one element to each segment of the carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) such that the segment attains a number of elements which is equal to the number of elements in the data word ($d(k)$), thus enabling a segment of the carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) and one of the at least one vector ($S_{IF-I}(k)$; $S_{IF-Q}(k)$) to be processed jointly by at least one of a SIMD-operation (multiple-bits multiplications) and an XOR-operation (1-bit multiplications).

9. (previously presented) A method according claim 1 further comprising the steps of:

determining a maximum variation a code rate due to Doppler-effects, defining a Doppler rate interval ($CR_{C-min} - CR_{C-max}$) around a center code rate (CR_c), the Doppler frequency interval having a lowest. code rate limit (CR_{C-min}) equal to the difference between the center code rate (CR_c) and the maximum code rate variation (CR_D), and a highest frequency limit (CR_{C-max}) equal to the sum of the center code rate (CR_c) and the maximum code rate variation (CR_D);

dividing the Doppler rate interval ($CR_{C-min} - CR_{C-max}$) into an integer number of equidistant (ΔCR) code rate steps (CR_{C-min} , $CR_{C-min} + \Delta CR$, ..., CR_{C-max}); and

defining a code rate candidate (CR_{c-c}) for each code rate step (CR_{C-min} , $CR_{C-min} + \Delta CR$, ..., CR_{C-max}).

10. (previously presented) A method according to claim 9 further comprising determining an integer number of possible initial code phase positions (0.0, ..., 0.9) for each code rate candidate (CR_{c-c}).

11. (previously presented) A method according to claim 10 further comprising defining, for each signal source specific code sequence (CS(i)), a set of combinations between code rate candidate (CR_{c-c}) and code phase position (0.0, ..., 0.9), each combination representing a code rate-phase candidate vector.

12. (previously presented) A method according to claim 11 further comprising generating, for each signal source specific code sequence (CS(i)), a set of code vectors (CV) by:

sampling each code rate-phase candidate vector with the basic sampling rate (r_s) whereby a corresponding code vector (CV) is produced.

13. (previously presented) A method according to claim 1 further comprising generating a modified code vector (CV_m) on basis of each code vector (CV) by:

copying a particular number of elements (E_e) from the end of an original code vector (CV) to the beginning of the modified code vector (CV_m); and

copying the particular number of elements (E_b) from the beginning of the original code vector (CV) to the end of the code vector (CV_m).

14. (previously presented) A method according to claim 13 further comprising storing, for each signal source specific code sequence (CS(i)), a set of modified code vectors ($\{CV_m(CR_{c-c}, Cph)\}$), where

each modified code vector (CV_m) contains a number of elements (s_1, \dots, s_m) representing a sampled version of at least one full code sequence (CS),

a particular modified code vector (CV_m) is defined for each combination of code rate candidate (CR_{c-c}) and code phase position (Cph).

15. (previously presented) A method according to claim 14 further comprising adapting the data format of the modified code vectors (CV_m) with respect to the data format of the at least one vector ($S_{IF-I}(k); S_{IF-Q}(k)$) derived from the data word ($d(k)$), such that a modified code vector (CV_m) and one of the at least one vector ($S_{IF-I}(k); S_{IF-Q}(k)$) may be processed jointly by at least one of a SIMD-operation (multiple-bits multiplications) and an XOR-operation (1-bit multiplications).

16. (previously presented) A method according to claim 14 further comprising involving an initial acquisition phase and a subsequent tracking phase, wherein during the acquisition phase a set of preliminary parameters are established which are required for initiating a decoding of signals received during the tracking phase, a successful acquisition phase resulting in at least one signal source specific code sequence (CS) being identified and a transmitted signal being rendered possible to track, each of the at least one signal source specific code sequence (CS) being associated with tracking characteristics in the form of:

- a modified code vector (CV_m),
- a carrier frequency candidate vector (f_{IF-C}),
- an initial phase position (ϕ_c),
- a code phase position (Cph), and
- a code index (CI) denoting a starting sample value for the modified code vector (CV_m).

17. (previously presented) A method according to claim 16 wherein said tracking involves:

- calculating, based on the tracking characteristics, a prompt pointer (P_p) for each modified code vector (CV_m), the prompt pointer (P_p) indicating a code sequence start position, and an initial prompt pointer (P_p) being equal to the code index (CI); and

- assigning, around each prompt pointer (P_p), at least one pair of early- and late pointers ($P_E, P_L; P_{E1}, P_{L1} P_{E2}, P_{L2}$), where the early pointer (P_E) specifies a sample value being positioned at least one element before the prompt pointer's (P_p) position, and the late pointer (P_L) specifies a sample value being positioned at least one element after the prompt pointer's (P_p) position.

18. (previously presented) A method according to claim 17, wherein said tracking involves:

- receiving a sequence of incoming level-discrete sample values (1210),
- forming data words ($d(1), \dots, d(N)$) of the sample values (1210) such that each data word ($d(k)$) contains a number of elements which is equal to the number of elements (S_n) in each carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$); calculating a

relevant set of carrier frequency-phase candidate vectors ($V_{f\phi}(f_{IF-C}, \phi_C)$) for the data word ($d(k)$); and

acquiring, for each carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) in the relevant set, a pre-generated in-phase representation (f_{IFI}) and a quadrature-phase representation (f_{IFQ}) of the vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) respectively.

19. (previously presented) A method according to claim 18, wherein said tracking involves:

multiplying each data word ($d(k)$) with the in-phase representation (f_{IFI}) of the carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$), in the relevant set to produce a first intermediate-frequency-reduced information word ($S_{IF-I}(k)$), multiplying each data word ($d(k)$) with the quadrature-phase representation (f_{IFQ}) of the carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) in the relevant set to produce a second intermediate-frequency-reduced information word ($S_{IF-Q}(k)$).

20. (previously presented) A method according to claim 19, wherein said tracking involves:

multiplying the first intermediate-frequency-reduced information word ($S_{IF-I}(k)$) with a modified code vector ($CV_{m-p}(k)$) starting at a position indicated by the prompt pointer (P_p) to produce a first prompt-despread symbol string ($\Lambda_{Ip}(k)$), multiplying the first intermediate-frequency-reduced information word ($S_{IF-I}(k)$) with a modified code vector ($CV_{m-E}(k)$) starting at a position indicated by an early pointer (P_E) to produce a first early-despread symbol string ($\Lambda_{IE}(k)$);

multiplying the first intermediate-frequency-reduced information word ($S_{IF-I}(k)$) with a modified code vector ($CV_{m-L}(k)$) starting at a position indicated by a late pointer (P_L) to produce a first late-despread symbol string ($\Lambda_{IL}(k)$);

multiplying the second intermediate-frequency-reduced information word ($S_{IF-Q}(k)$) with a modified code vector ($CV_{m-p}(k)$) starting at a position indicated by the prompt pointer (P_p) to produce a second prompt-despread symbol string ($\Lambda_{Qp}(k)$);

multiplying the second intermediate-frequency-reduced information word ($S_{IF-Q}(k)$) with a modified code vector ($CV_{m-E}(k)$) starting at a position indicated by the early pointer (P_E) to produce a second early-despread symbol string ($\Lambda_{QE}(k)$); and

multiplying the second intermediate-frequency-reduced information word ($S_{IF-Q}(k)$) with a modified code vector ($CV_{M-L}(k)$) starting at a position indicated by the late pointer (P_L) to produce a second late-despread symbol string ($\Lambda_{QL}(k)$).

21. (previously presented) A method according to claim 20, wherein said tracking involves deriving, for each despread symbol string, a resulting data word ($D_{R-IP}(k)$, $D_{R-IE}(k)$, $D_{R-IL}(k)$, $D_{R-QP}(k)$, $D_{R-QE}(k)$; $D_{R-QL}(k)$).

22. (currently amended) A method according to claim 21 wherein said deriving comprises deriving the resulting data words ($D_{R-IP}(k)$, $D_{R-IE}(k)$, $D_{R-IL}(k)$, $D_{R-QP}(k)$, $D_{R-QE}(k)$; $D_{R-QL}(k)$) by looking up a respective pre-generated value in a table (1310).

23. (previously presented) A method according to claim 19, wherein multiplying comprises performing the multiplication between the data word ($d(k)$) and the in-phase representation (f_{IF-I}) of the carrier-frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) respective between the data work ($d(k)$) and the quadrature-phase representation (f_{IF-Q}) of the carrier frequency-phase candidate vector ($V_{f\phi}(f_{IF-C}, \phi_C)$) by means of at least one of a SIMD-operation (multiple-bits multiplications) and an XOR-operation (1-bit multiplications).

24. (previously presented) A method according to claim 19, wherein multiplying comprises performing the multiplication between the intermediate-frequency-reduced information words ($S_{IF-I}(k)$; $S_{IF-Q}(k)$) and the modified code vectors (CV_{m-p} , CV_{m-E} ; CV_{m-L}) by means of at least one of a SIMD-operation (multiple-bits multiplications) and an XOR-operation (1-bit multiplications).

25. (previously presented) A method according to claim 19 further comprising propagating, in connection with completing the processing of a current data word ($d(k)$) and initiating the processing of a subsequent data word ($d(k+1)$):

a pointer (P_d) indicating a first sample value of the subsequent data word ($d(k+1)$);

a group of parameters describing the relevant set of carrier frequency-phase candidate vectors ($V_{f\phi}(f_{IF-C}, \phi_C)$);

the relevant set of code vectors (CV_m); and
prompt-, early-, and late pointers (P_P , P_E , P_L).

26. (previously presented) A computer program directly loadable into the internal memory of a computer, comprising software for controlling the steps of claim 1 when said program is run on the computer.

27. (previously presented) A computer readable medium, having a program recorded thereon, where the program is to make a computer control the steps of claim 1.

28. (currently amended) A signal receiver (~~1500~~) for receiving navigation data signals transmitted in a navigation satellite system comprising:

a radio front end unit (~~1510~~) adapted to receive a continuous radio signal (S_{HF}) and in response thereto produce a corresponding electrical signal (S_{IF}) comparatively high frequency;

an interface unit (~~1520~~) adapted to receive the electrical signal (S_{IF}) and in response thereto produce a sequence of sample values being divided into data words ($d(k)$);

a digital processor unit (~~1530~~) adapted to receive the data words ($d(k)$) and in response thereto demodulate a data signal and including a memory means; and

a computer program according to claim 16 is loaded in the memory means (~~1535~~).

29. (new) A software receiver comprising:

a receiver capable of receiving a radio signal;

means for digitizing the radio signal; and

a software correlator capable of mixing the digitized radio signal to form a baseband signal using bit-wise parallelism.

30. (new) The software receiver of claim 29 wherein said software correlator comprises:

means for computing correlations between the baseband signal and at least one pseudo-random number (PRN) code using the bit-wise parallelism.

31. (new) The software receiver of claim 30 wherein said software correlator further comprises:

means for computing accumulations from the correlations using the bit-wise parallelism.

32. (new) The software receiver of claim 31 further comprising:
application-specific code capable of computing navigation data using the accumulations.

33. (new) The software receiver of claim 29 wherein said means for digitizing comprises:

means for down-converting the radio signal to an intermediate frequency; and
a digitizer capable of digitizing the intermediate frequency.

34. (new) The software receiver of claim 33 wherein said digitizer produces at least one bit/sample.

35. (new) The software receiver of claim 33 wherein said digitizer is an analog to digital converter.